

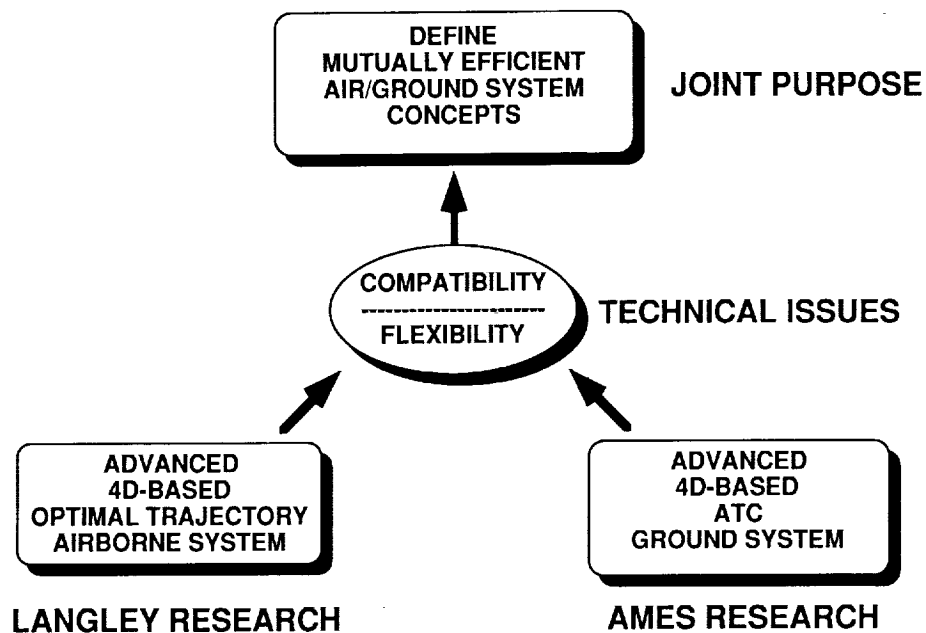
**TIME-BASED AIRCRAFT/ATC  
OPERATIONS STUDY**

**David H. Williams  
NASA Langley Research Center**



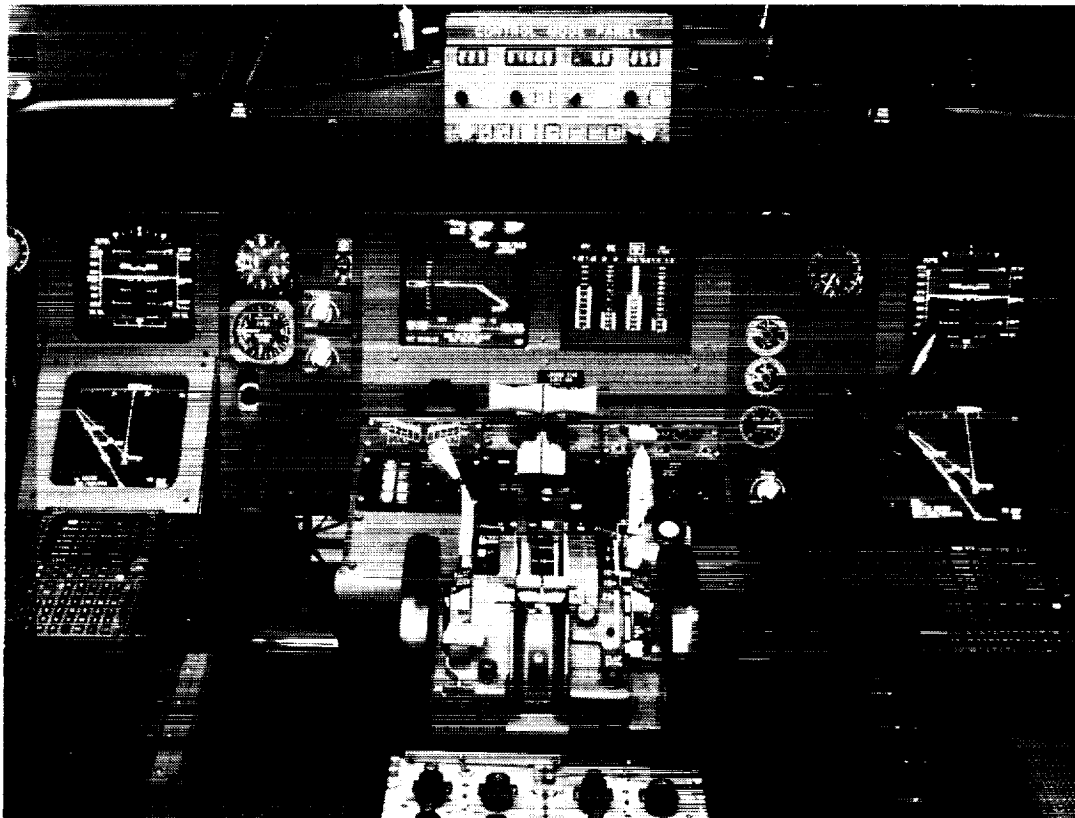
# **TIME-BASED AIRCRAFT/ATC OPERATIONS STUDY**

(JOINT LaRC /ARC SIMULATION)



## **STUDY OBJECTIVES**

- **DEVELOP AND EVALUATE PROCEDURES FOR INCORPORATING 4D-EQUIPPED AIRCRAFT INTO A 4D ATC SYSTEM**
- **DETERMINE IMPACT ON THE SYSTEM OF DISSIMILAR AIRBORNE AND GROUND 4D SPEED STRATEGIES**
- **EVALUATE EFFECTIVENESS OF AIRBORNE TIME GUIDANCE**



## NASA TSRV 4D FMS CAPABILITIES

### TRAJECTORY GENERATION

HORIZONTAL ROUTE DEFINED THROUGH FLEXIBLE CDU OPERATIONS.  
(COMPARABLE TO B-737-400)

VERTICAL TRAJECTORY GENERATION WITH ARRIVAL TIME CONSTRAINT.

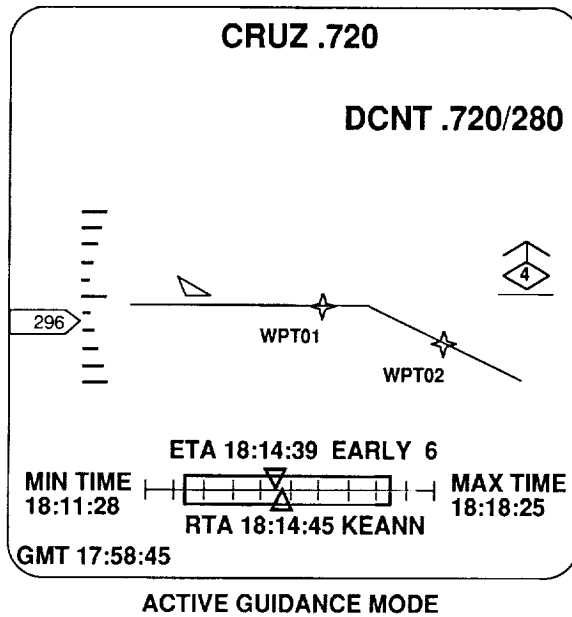
- MINIMUM FUEL
- ATC DESCENT ADVISOR

AUTOMATIC RECALCULATION CAPABILITY.

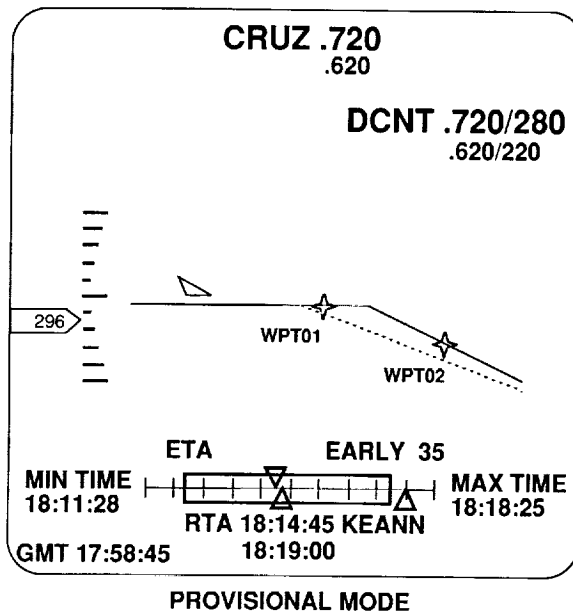
### 4D GUIDANCE

VERTICAL SITUATION DISPLAY WITH TIME CAPABILITIES SHOWN AT ARRIVAL FIX.  
TIME-BASED ENERGY ERROR DISPLAY.

# TSRV VERTICAL SITUATION DISPLAY



# TSRV VERTICAL SITUATION DISPLAY



## AIRBORNE 4D PROCEDURES

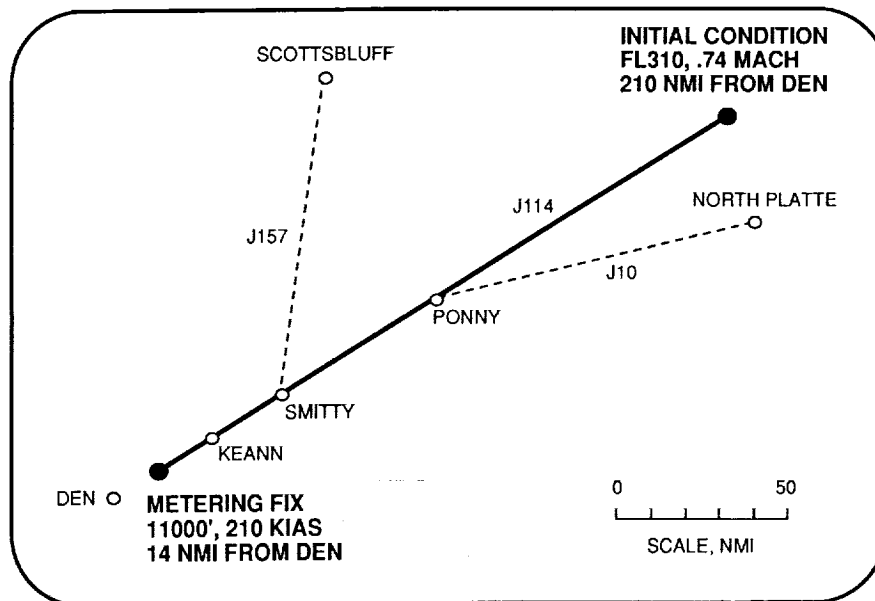
- **TIME CLEARANCE**

- ACKNOWLEDGE ATC
- ENTER ARRIVAL TIME
- EXECUTE NEW VERTICAL PROFILE
- ADVISE ATC OF SPEED CHANGE

- **TIME DELAY VECTOR**

- ACKNOWLEDGE ATC
- FLY ATC-SPECIFIED VECTOR AT MINIMUM SPEED
- ADVISE ATC OF SPEED CHANGE
- ENTER ARRIVAL TIME
- SELECT DIRECT INTERCEPT OF ATC-SPECIFIED WAYPOINT  
    << AUTOMATIC PROFILE RECALCULATION >>
- EXECUTE NEW PROFILE WHEN TIME DELAY COMPLETE
- ADVISE ATC WHEN TURNING BACK

## TEST SCENARIO



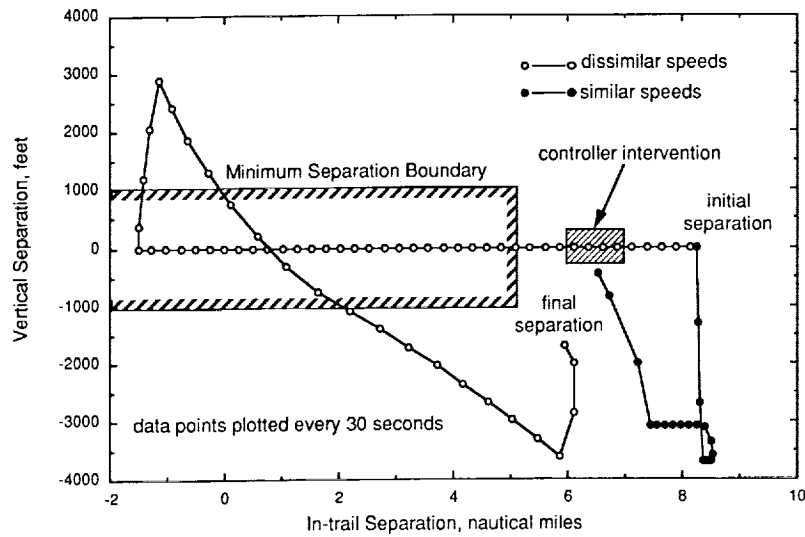
## TEST CONDITIONS

	CONDITION NUMBER				
	1	2	3	4	5
<b><u>TRAFFIC LEVEL</u></b>					
MODERATE	X	X	X		
HEAVY				X	X
<b><u>SPEED STRATEGY</u></b>					
MINIMUM FUEL		X	X		X
DESCENT ADVISOR	X			X	
<b><u>HORIZONTAL ROUTE</u></b>					
NORMAL	X	X		X	X
OFFSET			X		
total number of runs (3 pilots)	6	9	4	7	2

## RESULTS

- **TIME CLEARANCES, PROCEDURES AND DISPLAYS WELL RECEIVED BY PILOTS**
- **DISSIMILAR AIR AND GROUND SPEED STRATEGIES PRODUCED POTENTIAL TRAFFIC CONFLICTS DURING MODERATE TRAFFIC**
  - ATC VECTORS AND ROUTE-OFFSET PROVED LESS EFFICIENT
  - CRUISE SPEED RESTRICTION COULD ALLEVIATE THE PROBLEM
- **TIME DELAY VECTOR USEFUL DURING HEAVY TRAFFIC**
  - POTENTIAL FOR RELIEVING CONTROLLER WORKLOAD
  - ALLOWS AIRCRAFT TO MINIMIZE DELAY RANGE
  - DISSIMILAR SPEEDS NOT A PROBLEM
- **TIME GUIDANCE PROVED VERY EFFECTIVE**
  - ARRIVAL TIME ERROR OF 2.9 SECONDS (STANDARD DEVIATION)

## SEPARATION CONFLICT INDUCED BY DISSIMILAR SPEED SCHEDULES



En route separation for 32 minute flight time with 80 seconds in-trail separation at initial and final conditions

## FUEL USAGE OF TSRV SIMULATOR

Aircraft Speed Strategy	Route	ATC Interruption	Number of runs	Average Fuel Used
Descent Advisor	normal	no	6	1779 (reference)
Minimum fuel	normal	no	6	1740 (-2.2%)
Minimum fuel	normal	yes	3	1891 (+6.3%)
Minimum fuel	offset	no	3	1800 (+1.2%)
Minimum fuel	offset	yes	1	1916 (+7.7%)

## **FUTURE PLANS**

- **TEST PROCEDURAL SOLUTIONS TO COMPATIBILITY PROBLEMS OF DISSIMILAR SPEED STRATEGIES**
- **EXPLORE DATA LINK APPLICATIONS**
  - UPLINK OF CLEARANCES AND SPEED CONSTRAINTS
  - DOWNLINK OF PLANNED SPEED SCHEDULE AND TOP OF DESCENT
- **INTEGRATE TIME GUIDANCE INTO PRIMARY DISPLAYS**
- **DETERMINE WIND AND TEMPERATURE MODELING REQUIREMENTS**
- **TEST SCENARIOS WITH MULTIPLE 4D AIRCRAFT**

## **SUMMARY**

- **AIRBORNE 4D CAN BE EFFECTIVELY INTEGRATED INTO AN ADVANCED 4D ATC SYSTEM**
- **DIFFERENCES IN 4D SPEED STRATEGIES CAN BE MANAGED WITH PROCEDURAL SOLUTIONS**
- **TIME GUIDANCE CONCEPTS VERY EFFECTIVE**
  - MUST NOW BE INTEGRATED INTO AIRLINE COCKPIT

